Why More Flood Disasters are Occurring (New Zealand Examples & Solutions)

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ABSTRACT: Most New Zealanders reside in coastal regions and four of the larger cities are situated on active floodplains. There have been many recent storm events with rainfall AEPs of 1/150 or rarer and there have been recent flood-related disasters. Insurance claim statistics indicate that the frequency of floods is increasing. Such statistics are alarming local government authorities, insurance companies and populations in low-lying areas. The underlying physical and hydrologic causes of the flood disasters are investigated. It is found that the present numbers of rare rainfall events are not unexpected and there does not appear to be any significant trend evident in the occurrence of river floods. What is revealed is that the river floods appear clustered in certain decades. The clusters do not occur at the same times in different parts of the county. Recently there have been more floods in the north of New Zealand which is where more of the population lives. Also, the increase in population has seen more houses built in locations prone to flooding. Thus the increase in flood-related insurance claims is attributed to more people getting in the way of floods, rather than an increase in the number of floods that have occurred.

1 INTRODUCTION

New Zealand is located 1,900 km from the nearest large land mass of Australia. It has two main islands situated between latitudes 34°S and 47°S in the South Pacific Ocean. Both the North Island and the South Island are mountainous with altitudes over 2,400 m in the North Island and Mount Cook rising past 3,700 m in the South Island. Most New Zealanders reside in the coastal regions and four of the larger cities are situated on active floodplains.

Recently, around the world, there have been many recent flood-related disasters. Although New Zealand's land area of 268 000 km^2 has a population of only 4 million inhabitants, it has also had a spate of such disasters. There have been many recent storm events with rainfall AEPs of 1/150 (2 in 1999, 2 in 2004, 1 in 2005 and 1 in 2007). Information on flood damages provided by insurance companies reveals 12 flood-related events each caused damages of NZ$1M or more since 1999. Of the 12 events, 11 occurred in the North Island. Such statistics are alarming local government authorities, insurance companies and populations in low-lying areas.

What is causing this apparent increase in flooding? This question is tackled as two separate problems: *are floods occurring more frequently than could be statistically expected?* and *are there more large floods than in the past?* The paper then addresses what can be done to help solve the problem.

2 ARE FLOODS OCCURRING MORE FREQUENTLY THAN COULD BE STATISTICALLY EXPECTED

A comparison with insurance payouts from earlier years (Fig. 1) shows that the number of flood events causing insurance claims each year has been steadily increasing over recent years. This suggests that the number of floods in populated areas is increasing.

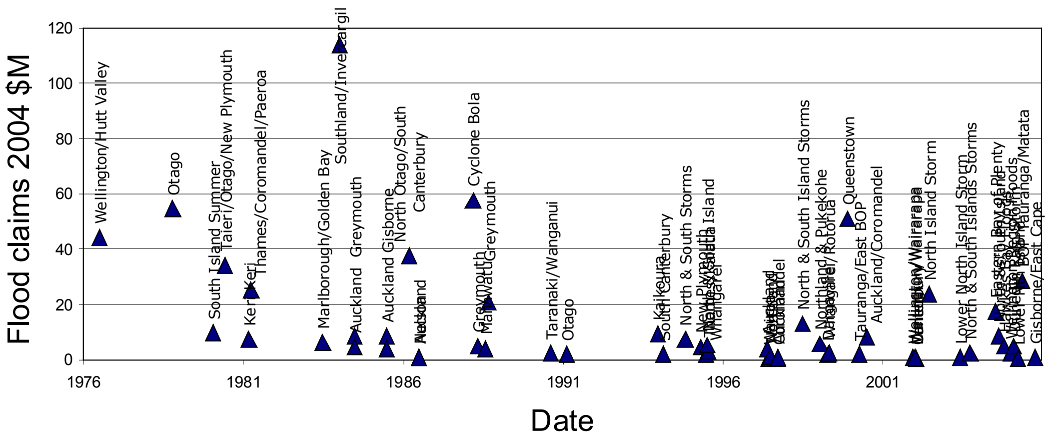

Fig. 1. Insurance claims for flood damages in New Zealand since 1976

To investigate the number of floods that can be expected in populated areas of New Zealand, it is necessary to define “populated”. New Zealand has many thousands of rural catchments containing individual dwellings but the dwellings may be sited away from flood-prone areas. In 1984 there were 36 New Zealand catchments with over 500 inhabitants. For an indicative present-day statistic it is assumed that New Zealand now has 100 catchments with floodable settlements.

On this basis and assuming that an event covering more than one populated catchment is counted as more than one flood, it is possible to calculate the probability of multiple floods per year using a binomial distribution. The results are shown in Table 1.

Table 1. Probability of floods in 100 “populated” New Zealand catchments.

Number per year	AEP 1/150 year	AEP 1/100 year	AEP 1/50 year
1 or more	.49	.63	.87
2 or more	.14	.27	.60
5 or more	.001	.003	.05

From these data it appears that in each year we should expect at least two 1/50 AEP floods and one 1/100 AEP flood. There are “even odds” ($p = 0.49$) of having one or more 1/150 AEP floods in a given year and a 14% chance of two or more. There is a 5% chance of 5 or more 1/50 AEP floods occurring in NZ’s “populated” catchments in a given year. This table suggests that the present numbers of extreme rainfall events are not unusual. For example, during the 1999 – 2007 years there were 4 years with 1 or more storms greater than the 1/150 AEP level. This 44% chance per year compares well with the expected 0.49 probability given in Table 1.

3 ARE THERE MORE LARGE FLOODS THAN IN THE PAST

More specific flood statistics are revealed by a data analysis carried out for catchments in the northern half of the South Island. Annual maxima series of stream flow records from the 38 main catchments in the northern half of the South Island were analysed to derive 1/5, 1/10, 1/50, and 1/100 AEP flood flows. Figure 2 shows the number of occurrences of floods larger that the 1/100 AEP threshold. There is no evidence that more frequent “hundred year” floods are occurring and there does not appear to be any significant trend evident in this figure.

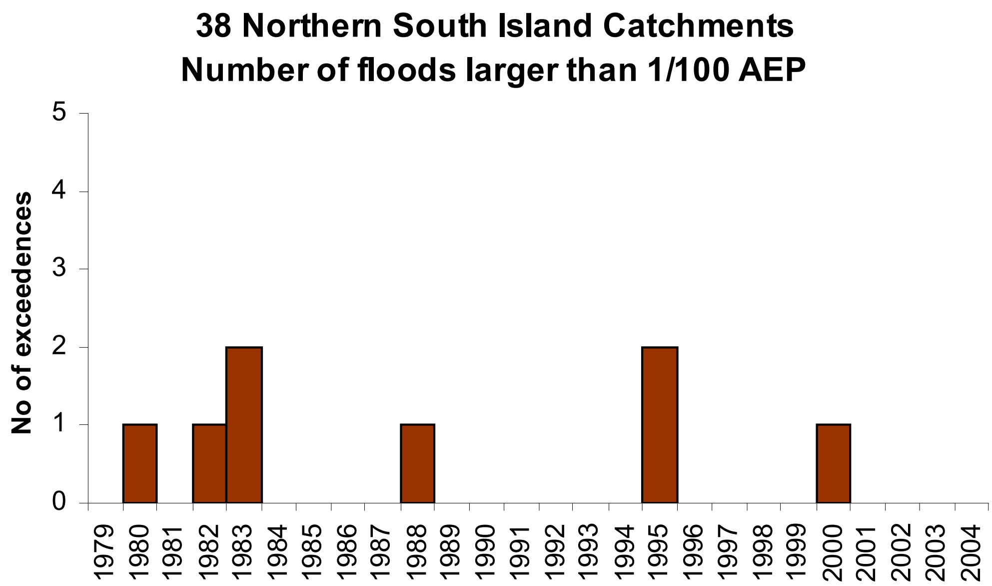

Fig. 2. Number of floods larger than 1/100 AEP occurring in 38 catchments in the top half of the South Island

Figure 3 shows the annual maxima series data for the 1979-2004 period from the northern South Island split into two equal halves, 1979-1991 and 1992-2004. The figure for the northern half of the South Island shows that there were fewer floods over the 1992-2004 period compared to the 1979-1991 period (see also McKerchar & Henderson, 2003). The ratio of the number of 1/5 AEP floods over the 1992-2004 period compared to the number in the 1979-1991 period was 0.7. For 1/20 AEP floods the ratio was also 0.7. This ratio is relatively constant when the numbers of floods in the two different periods are compared at the other AEP levels. Consequently, the occurrence of smaller floods (e.g. 1/5 AEP floods) can be used to indicate the occurrence of larger floods (say 1/100 AEP floods).

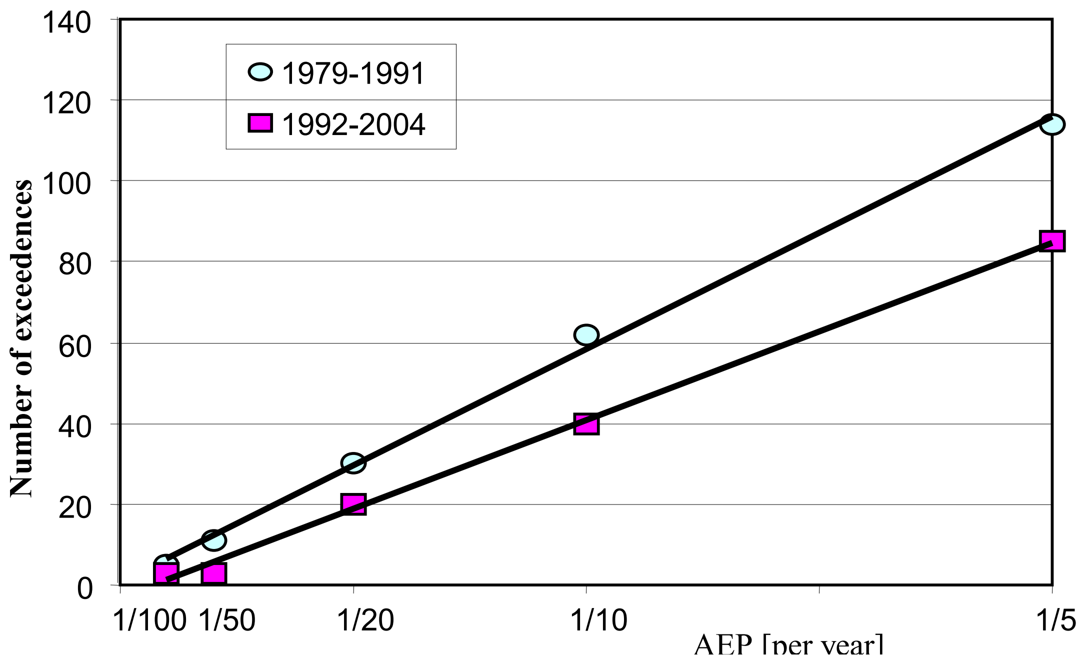

Fig. 3. Number of floods in 38 main catchments of the north of the South Island in successive 13 year periods

Although comprehensive statistics have not yet been compiled for other parts of New Zealand, it is assumed that the occurrence of smaller floods in other regions can be used to indicate the frequency of larger floods in these regions. The dark bars on Figure 4 shows floods larger than 1/5 AEP which occurred in the Whakatane River (1500 km^2 catchment, flow range 6 – 850 m^3/s) on the east coast of the North Island of New Zealand. Fig. 4 indicates clustered floods but there is not an increasing trend with time in the number of floods. For comparison, the frequency of floods larger than 1/100 AEP in the northern South Island is also shown on Fig. 4. as light coloured bars. From Fig. 4 it appears that floods tend to occur clustered in groups but the northern South Island floods do not coincide with the eastern North Island floods.

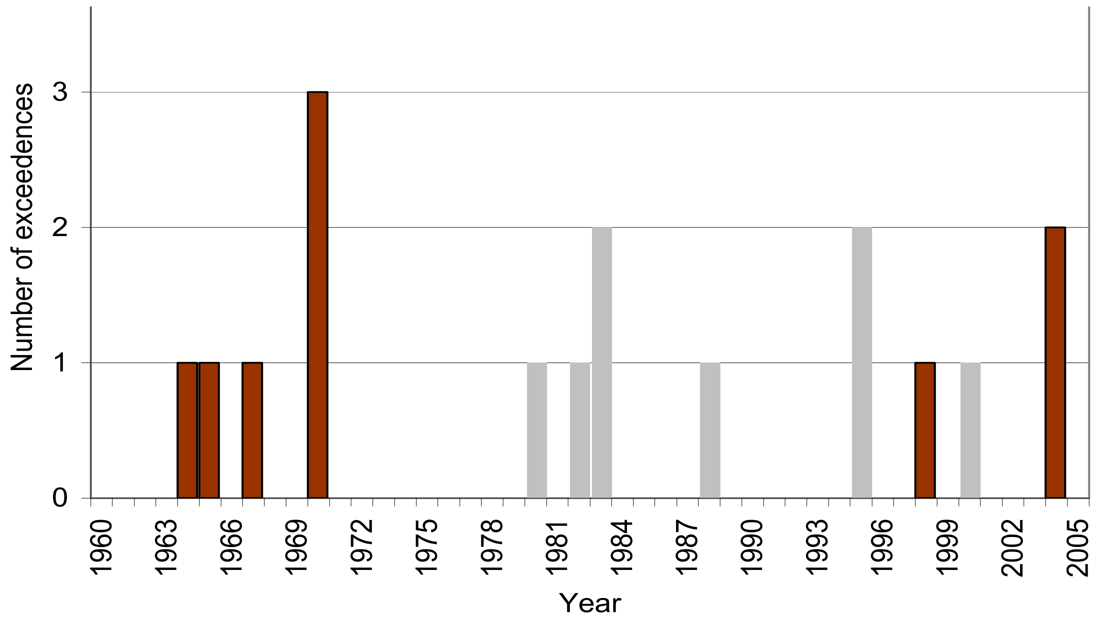

Fig. 4. Number of floods larger than 1/5 AEP occurring in the Whakatane River, Eastern North Island (dark bars). Also showing the number of floods larger than 1/100 AEP in the northern South Island (light bars).

Although there has been an increase in the number of insurance claims for flood damages, on the basis of these investigations it would appear that there has not been a corresponding increase in the frequency or severity of rainfall or flood events. There appear to be clusters of floods at different times in the North and South Islands. This suggests that climatic effects may be responsible.

4 CLIMATIC EFFECTS

Fig. 5 shows the average temperatures in New Zealand since 1853. These annual data show there can be dramatic shifts over two or three years. From 1916 to 1919 the change was 1.58 degrees and from 1990 to 1992 the change was 1.49 degrees (due to the 1991 eruption of Mt Pinatubo).

The smoothed data (dark line) on Fig. 5 shows a distinct pattern of warmer and cooler periods with a variable periodicity of around a decade or more. Since 1900 a trendline indicating an increase of 1 degree Celsius every 100 years can be fitted (dotted line). This is attributed to global warming. Note that the inter-annual variability of more than 1.5 degrees is equivalent to 150 years of global warming. The inter-annual changes can be two orders of magnitude greater than the global warming trend and this may explain why many people do not recognize global warming. When Fig. 5 is compared with Fig. 4, there does not appear to be any relation between the temperature fluctuations and the location or occurrence of river floods.

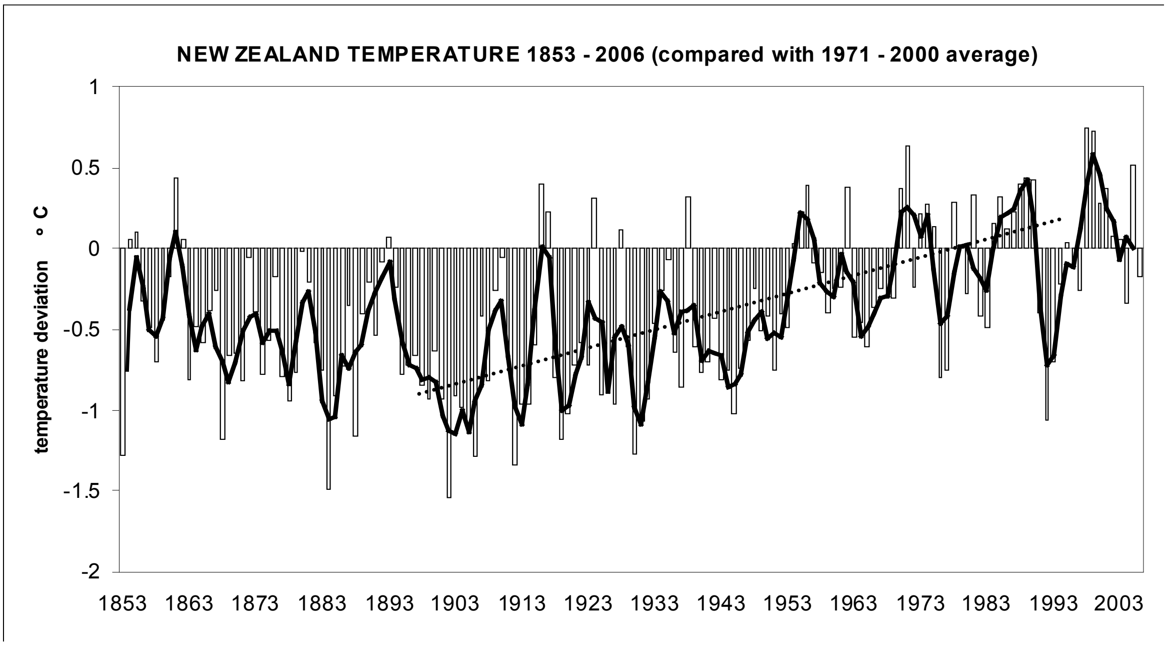

Fig 5. Bars show New Zealand annual average temperatures from 1853-2006 as deviations from the 1971-2000 average temperature. The dark line shows the 5-year smoothed temperature. The dotted line shows a linear trend fitted since 1900.

The location of floods is determined by atmospheric circulation patterns and the effect of global climate indices on these patterns is now investigated. Figure 6 shows the Southern Oscillation Index and the Inter-decadal Pacific Oscillation indices since 1930. A cool IPO phase occurred from 1946-1977 and a warm phase followed. The cool phase was accompanied by frequent La Nina conditions and the warm phase saw frequent El Nino conditions. Under the El Nino conditions moist airflows approach New Zealand from the west. Under La Nina conditions high pressures tend to persist to the east of New Zealand.

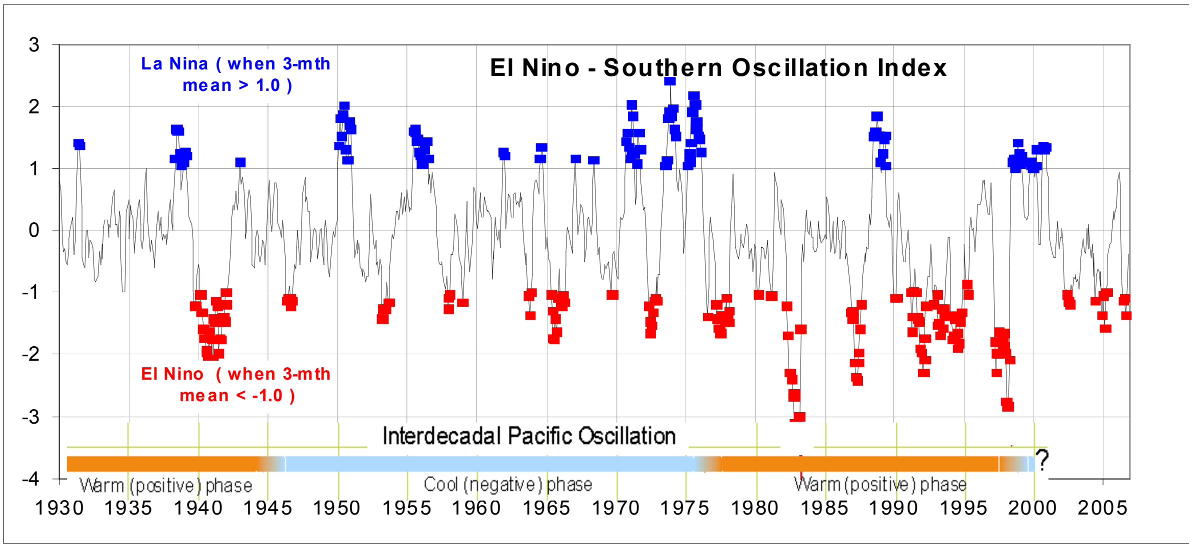

Fig 6. Southern Oscillation and Interdecadal Pacific Oscillation indices since 1930.

To investigate any effect of the IPO, rainfall totals in different parts of New Zealand are compared in Fig. 7 which shows the rainfall difference between the 1978-1999 warm period and the 1946-1977 cool period. The east and north of the North Island had less total rainfall post 1977 compared to the 1946-1977 cooler period. The north of the South Island had more total rainfall during the 1978-1999 warmer period. The north east of the North Island had less rainfall during the warm 1978-1999 period when there were no floods in the Whakatane River (Fig. 4) in the east of the North Island. The changes in rainfall totals correspond to the changing location of floods. This analysis suggests that inter-decadal global circulation patterns affect where floods occur in New Zealand.

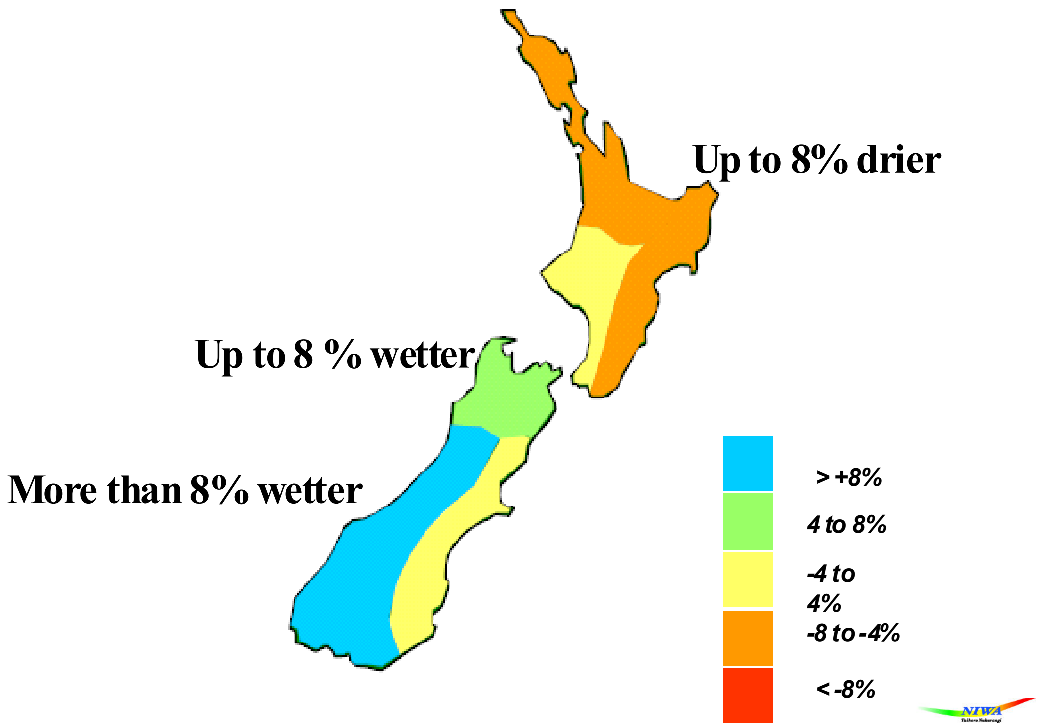

Fig 7. Rainfall from 1978-1999 compared with rainfall from 1946-1977.

5 POPULATION MOVEMENTS

As the population of New Zealand has grown, more people have settled in the north of the country than in other regions. Also more of the population is now living on floodplains. Government planning and flood control works are supposedly used to protect the population from floods. Compliance with the NZ Building Act requires that surface water from 2% AEP events shall not enter housing. From Table 1 there is an 87% chance of 1 or more 2% floods in populated NZ every year. In other words, the population is permitted to build in areas subject to floods greater than the 2% AEP flood magnitude.

Although there is no evidence of an overall increase in the number or size of floods in New Zealand, the frequency of insurance claims is increasing because recent floods have occurred in the North Island where more people live and because more people are building in locations that expose them to flood hazards.

6 REDUCING FLOOD DAMAGE

To reduce the amount of flood damage it is necessary to reduce the flood hazard. Flood hazard can only be avoided if it is understood where floods will occur. This entails the production of flood maps. These can be drawn on the basis of measurements of historic floods if such data are available. Unfortunately New Zealand does not have long-term records of flood inundation and it is necessary to calculate where flood inundation will occur. This is currently being carried out by using airborne laser surveys to accurately map ground topography and by using high resolution, two dimensional computational hydraulic models to predict inundation extent, depths and velocities. An example of typical results from a computational flood model is shown in Fig. 8. The computational models take considerable time to calibrate and implement but are proving invaluable for predicting areas of flood hazard.

Fig. 7. Balclutha township during a 1998 flood (top) and results of 2D hydrodynamic modeling of the same flood (bottom).

7 SUMMARY AND CONCLUSIONS

While there has been an increase in flood-related insurance claims in New Zealand, there has not been a noticeable overall increase in extreme rainfalls or flood frequency. It was found, however, that the locations of extreme rainfalls change with inter-decadal global circulation patterns.

Recently there have been more floods in the north of New Zealand which is where more of the population lives. Also, the increase in population has seen more houses built in locations prone to flooding. Thus the increase in flood-related insurance claims is attributed to more people getting in the way of floods, rather than an increase in the number of floods that have occurred.

Flood maps are now being computed to identify areas of flood hazard and it is hoped that flood damages can be reduced in the future.

8 REFERENCES

McKerchar A.I., Henderson R.D., (2003): "Shifts in flood and low-flow regimes in New Zealand due to interdecadal climate variations". Hydrological Sciences Journal 48(4), p637-654.